MORPHOMETRIC ANALYSIS OF DIAPHRAGMA SELLA –

AN ANATOMICAL STUDY

Dissertation submitted to

M.Ch., (BRANCH II – NEUROSURGERY – 5 YEARS)

August - 2008

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,

CHENNAI. TAMILNADU

DEPARTMENT OF NEUROLOGY & NEUROSURGERY

MADURAI MEDICAL COLLEGE

MADURAI.

CERTIFICATE

This is to certify that this dissertation titled "**MORPHOMETRIC ANALYSIS OF DIAPHRAGMA SELLA – AN ANATOMICAL STUDY**" is an original bonafide work conducted by **Dr. V.Suresh Kumar** at Madurai Medical College & GRH, Madurai under my guidance and supervision.

Dr.M. SHANTHI, M.D.,	**Prof. S.MANOHARAN,** M.Ch.,
The Dean, Madurai Medical College & GRH Madurai.	Pro. & Head of the Department Dept. of Neurology & Neurosurgery Madurai Medical College & GRH Madurai.

ACKNOWLEDGEMENT

My sincere thanks to **The Dean,** Madurai Medical College and Government Rajaji Hospital, Madurai for permitting me to do this dissertation.

I acknowledge with gratitude the dynamic guidance given to me by my **Prof .Dr S. Manoharan,** Head of Department of Neurology and Neurosurgery.

I sincerely thank, **Prof. Dr. D.Kailairajan, and Prof. Dr Ashok Kumar** Department of Neurology & Neurosurgery, for their persistent encouragement.

With heart felt gratitude I thank **Prof Dr. K.Meiazhagan**, Head of Department of Forensic science & toxicology, for permitting me to do cadaver dissections.

I wish to thank **Assistant Professors, Department of Neurology** and **Neuro Surgery**, who were always ready to render help whenever needed.

I take this opportunity to express my respect to **Prof. Dr.V. Inbasekaran,** & **Prof. Dr. V.G. Ramesh** for their untiring support.

I wish to thank **Mr.M. Parthasarathy** for his assistance and guidance in statistical work.

INTRODUCTION

The diaphragma sella, is the dural membrane in the sellar region and forms the roof of the hypophysis. Despite immense clinical as well as surgical implications very few dedicated studies are available on this structure. Radiological identification of this membrane is also not possible except for few indirect clues which suggest the competence.

Anatomical knowledge about this membrane is indispensable during surgical approaches for the lesions in and around the sella. In intra sellar pathologies like pituitary adenomas, if this membrane is intact and competent, transsphenoidal resection becomes much safer and easier. In intra sellar lesions, the incidence of intra-operative as well as post-operative CSF leak depends on the competency of the diaphragma sella. A deficient diaphragma sella is most often associated with intra sellar arachnoidocele ,more prone to intra operative and post operative CSF leak, thus necessitating sellar floor repair.

In the era of endoscopic surgery, extended transsphenoidal approaches where the resection of diaphragma sella is a part of the surgery , emphasizes the need for recognition of the anatomical details of this membrane. Resection of supra diaphragmatic portions of pituitary adenomas and craniopharyngiomas as well as resection of other supra diaphragmatic lesions through the normal sella is also possible nowadays, and hence the need to know more about the morphology of diaphragma sella.

Transsphenoidal surgery helps in the resection of ACTH-producing adenomas located in the pituitary stalk or extending into the stalk from the superior aspect of the anterior lobe, and preservation of pituitary stalk is possible in most patients, when compared to transcranial approach. Resection of diaphragma sella is often required in this procedure.

The various pathological and surgical implications of diaphragma sella, makes this membrane instrumental in the sellar region. Hence anatomical knowledge of this membrane is mandatory.

ANATOMY OF THE SELLAR REGION

The pituitary gland and sella are located below the center of the brain in the center of the cranial base.

The hypophysis consists of two embryologically different elements: an ectodermal part (antehypophysis) that migrates caudocranially, and a neuroectodermal one (neurohypophysis) that migrates craniocaudally. The sella turcica is a sagittally concave bone groove located at the posterosuperior portion of the body of the sphenoid bone. It is limited anteriorly by the tuberculum sellae and posteriorly by the dorsum sellae and posterior clinoid processes (the upper part of the clivus). Conversely, there are no lateral bone limits, and the sella turcica opens directly into the paired laterosellar spaces. The floor of the sella turcica is continuous in the adult.

The diaphragma sellae forms the roof of the sella turcica. It covers the pituitary gland, except for a small central opening in its center, which transmits the pituitary stalk. The diaphragma is more rectangular than circular, tends to be convex or concave rather than flat, and is thinner around the infundibulum and somewhat thicker at the periphery. It is frequently a thin, tenuous structure that would not be an adequate barrier for protecting the suprasellar structures during trans sphenoidal surgery. The diameter of the hypophyseal foramen is always larger than the pituitary stalk. The depth of the hypophyseal cistern (located in the free space around the pituitary stalk) is usually less than 2 mm.

The dural bag contains the anterior and posterior parts of the hypophysis. The former bulges laterally into the cavernous sinuses and the latter bulges dorsally, creating a small posterior lodge . The anterior lobe wraps around the lower part of the pituitary stalk to form the pars tuberalis. The posterior lobe is softer, almost gelatinous, and is more densely adherent to the sellar wall. The anterior lobe is firmer and is more easily separated from the sellar walls. The gland's width is the same or more than either its depth or its length in most patients. Its inferior surface usually conforms to the shape of the sellar floor, but its lateral and superior margins vary in shape because these walls are composed of soft tissue rather than bone. The hypophyseal stalk arises from the infundibulum, extends through the diaphragmatic foramen, and reaches the posterior part of the hypophysis. The portion of the hypophysis located just below the diaphragmatic foramen, around the hypophyseal stalk, is concave superiorly, similar to the small depression around an apple stem. This small depression is usually less than 2 mm deep and contains the hypophyseal cistern, which is located between the hypophyseal stalk, the upper limit of the hypophysis, and the border of the hypophyseal foramen. The hypophyseal cistern is an expansion of the chiasmatic subarachnoidal cistern and is separated from the interpeduncular or prepontine subarachnoidal cistern by the Liliequist membrane. The nerve relationships of the hypophyseal fossa are numerous: the fossa is located below the floor of the third ventricle,

the optic nerves, and chiasm. The oculomotar (third) and trochlear (fourth) cranial nerves perforate the roof of the cavernous sinus just medial to the anterior petroclinoid fold. The dural foramina of the third

and fourth cranial nerves are located at the medial and posterior thirds, respectively, of the anterior petroclinoid fold (near the junction of the two petroclinoid folds). These two nerves then run laterally to the intracavernous carotid artery, near the inner aspect of the lateral wall of

the cavernous sinus, to reach the superior orbital fissure. The ophthalmic and maxillary nerves (first and second divisions of the trigeminal nerve, respectively) also run near the inner aspect of the lateral wall of the cavernous sinus, below the third and fourth cranial nerves. They join the mandibular nerve (third division of the trigeminal nerve) to form the trigeminal ganglion, plexus, and trunk.

Venous sinuses that interconnect the paired cavernous sinuses may be found in the margins of the diaphragma and around the gland. The intravenous connections within the sella are named on the basis of their relationship to the pituitary gland; the anterior intravenous sinuses pass anterior to the hypophysis, and the posterior intravenous sinuses pass behind the gland. Actually, these intravenous connections can occur at any site along the anterior, inferior, or posterior surface of the gland, or all connections between the two sides may be absent. The anterior intra cavernous sinus may cover the whole anterior wall of the sella. The anterior sinus is usually larger than the posterior sinus, but either or both may be absent. If the anterior and posterior connections coexist, the whole structure constitutes the "circular sinus." Entering an anterior inter cavernous connection that extends downward in front of the gland during transsphenoidal operation may produce brisk bleeding.

LESIONS INVOLVING SELLAR REGION

Common lesions and their differential diagnosis by location are as follows:

INTRASELLAR

Common

Physiologic hypertrophy

Microadenoma

Cyst - Rathke cleft cyst, pars intermedia.

Rare

Craniopharyngioma

Metastasis

Rare but important

Aneurysm of cavernous sinus internal carotid artery.

INFUNDIBULAR STALK

Uncommon

Germinoma

Lymphoma

Sarcoid

Histiocytosis

Metastasis

Meningitis

Astrocytoma

Leukemia

Rare

Pitucytoma

Choristoma

Hypophysitis

SUPRASELLAR

Common

Pituitary macro adenoma

Meningioma-

Tuberculum sellae

Diaphragma sellae

Dorsum sellae.

Aneurysm - paraclinoid and supra clinoid internal carotid artery.

Craniopharyngioma.

Chiasmal Glioma

Uncommon

Lipoma

Dermoid

Metastasis

Cysts- Arachnoid cyst

Rathke cleft cyst.

Ectopic neurohyphophysis.

Rare

Hamartoma

Hypophysitis

COMMON PATHOLOGIES INVOLVING SELLA

PITUITARY ADENOMA

Pituitary tumors are common lesions accounting for 10% to 15% of all primary brain tumors[13]. Epidemiological estimates indicate an annual incidence of 8.2 to 14.7 cases per 100,000 people[1]. Pituitary adenomas are divided in to micro adenomas (< 1cm) and macro adenomas (>1cm). Macroadenomas which are > 4cm in vertical diameter are known as Giant pituitary adenomas[7].

Based on this definition , giant pituitary adenomas account for approximately 5% of all pituitary adenomas. In cases of pituitary macro adenomas and giant pituitary adenomas tumoral morphology depends on the morphology of diaphragma sellae, which also influences the surgical approaches. The pituitary adenomas which is dumbbell shaped with narrow waist is due to constriction created by thick diaphragma sellae and by the opening for the pituitary stalk that is very small[26].

MENINGIOMAS

True intra sellar meningiomas are very rare. Occasionally, a true diaphragma sellae or tuberculam sellae meningioma grows downward in to pituitary fossa. In such cases, a thickened, depressed diaphragma

sellae below the the enhancing mass which separates it from the pituitary gland can be visualised[32].

CRANIOPHARYNGIOMA

Only 5 to 10% of craniopharyngiomas are purely intersellar[20]. In this situation, it closely resembles Rathke cleft cyst. But 52% of all craniopharyngiomas involve sella turcica[25]. Those tumors that have a considerable supra sellar component may be readily removed transsphenoidally if they have elevated diaphragma sellae on their upper surface with the tumor remaining sub diaphragmatic[10].

SURGICAL APPROACHES TO SELLAR REGION

Various surgical corridors are available to manage the lesions involving sellar region. The two major avenues are transsphenoidal and transcranial approaches.

Standard transsphenoidal approaches

Endonasal submucosal transeptal transsphenoidal approach Endonasal submucosal septal pushover approach Sublabial transseptal transsphenoidal approach Endoscopic Endonasal transsphenoidal approach.

Standard transcranial approaches

Pterional craniotomy

Subfrontal craniotomy

Subtemporal craniotomy

Alternative skull base approaches

Cranial orbital zygomatic astronomy approach

Extended transsphenoidal approach

Trans basal approach of Derome

Lateral rhinotomy or paranasal approaches

Sublabial transantral approach

Transethmoidal and extended transethmoidal approaches

Sublabial transeptal approach with nasomaxillary astronomy

Among these approaches, majority of intra sellar lesions can be managed with transsphenoidal route. In cases of intrasellar lesions with intra cranial extension, various strategies are available. Nature of diaphragma sellae plays crucial role in deciding the approaches.

Usually, intrasellar lesions with intracranial extension, as long as the lesion stays sub diaphragmatically can be resected with transsphenoidal approach. The indication most often cited for a transcranial approach is the dumbbell shaped pituitary adenomas with a narrow waist caused by narrow opening diaphragma sellae[34].

With improved microsurgical techniques and endoscopic applications, management of supra diaphragmatic lesions through enlarged as well as normal sellae is also possible. Modifications of transsphenoidal surgery such as extended transsphenoidal approaches like transsphenoidal presellar, transsphenoidal transellar trans-diphraghmatic approaches are also being used for supra diaphragmatic lesions which extend in to tuberculum sellae and dorsum sellae. Both these surgical corridors necessitate resection of diaphragma sellae.

REVIEW OF LITERATURE

Morphology of diapharagma sella is implicated in development of hypophysis, various pathological process, and surgical corridors.

Very few dedicated studies are available regarding this membranous structure.

Unfortunately, this membrane morphology can not be identified by radiological measures directly.

Bush. W.[3] described and classified diaphragma sella based on the thickness of the membrane and its opening for stalk. His classification as follows,

Type 1 a	:	The diaphragma sella forms a complete seal.
Type 1 b	:	slight tunnel shaped depression in the intact diaphragma sella
Type 2 a	:	An opening, 3mm or smaller, in the diaphragma sellae exists around the hypophyseal stalk
Type 2 b	:	A slight funnel shaped indentation towards middle of sellae.
Type 3 a	:	The diaphragma sella is composed of 2 mm or smaller peripheral weil leaving the gland freely exposed and covered with arachnoid.

Type 3 b	:	Diaphragma sella as in 3a but pituitary gland intended, often displaced eccentrically.
Type 3 c	:	Diaphragma sella as in 3a but pituitary gland is markedly intended.

Following this, ***Kaufman***[11] found that 6 to 7 % of the specimens were of type 3 C. Both studies excluded known endocrine problems as well as enlarged pituitary gland specimens.

Christophe destrieux et al[4] , analysed the anatomy of sellar region and described the horizontal dural layer that ran from one anterior petroclinoid fold to the other. It was continued anteriorly by the dura mater covering the tuberculum sellae and posteriorly by the dura mater surrounding the upper clivus. Laterally, its direction changed and it became nearly vertical to reach the line joining the rotundum and ovale foramina. This vertical part of the dural layer constituted the lateral wall of the cavernous sinus. The continuous horizontal layer spreading between the two anterior petroclinoid folds was the roof of the sellar and parasellar regions. Laterally it is called the roof of the cavernous sinus and on the midline it is known as the diaphragma sellae, because it is pierced by the diaphragmatic foramen.

The latter was round or oval and contained the hypophyseal stalk and the terminal segment of the superior hypophyseal arteries that followed the stalk. The diameter of the diaphragmatic foramen was always more than twice the diameter of the hypophyseal stalk. In the adult brains, the diaphragmatic foramen was smaller than the bag (as if the bag were half closed). The bag closely surrounded the hypophysis, had the same shape, and isolated the hypophysis from all the structures around it, particularly the cavernous sinuses. In other words, the lateral walls of the hypophyseal fossa were not straight sagittal dural layers, but rather the lateral parts of this anteroposterior and superoinferior convex dural bag. The portion of the hypophysis located just below the diaphragmatic foramen, around the hypophyseal stalk, was concave superiorly, similar to the small depression around an apple stem. This small depression was less than 2 mm deep and contained the hypophyseal cistern, which was located between the hypophyseal stalk, the upper limit of the hypophysis, and the border of the hypophyseal foramen. The hypophyseal cistern was an expansion of the chiasmatic subarachnoidal cistern and was separated from the interpeduncular or prepontine subarachnoidal cistern by the Liliequist membrane.

Albert rhoton, Jr.,[25] described that the diaphragma sellae forms the roof of the sella turcica. It covers the pituitary gland, except for a small central opening in its center, which transmits the pituitary stalk. The diaphragma is more rectangular than circular, tends to be convex or concave rather than flat, and is thinner around the infundibulum and somewhat thicker at the periphery. It frequently is a thin, tenuous structure that would not be an adequate barrier for protecting the suprasellar structures during transsphenoidal operation.

Renn and Rhoton[24] also described in their earlier anatomic study that the diaphragma was at least as thick as one layer of dura in 38% and in most cases it furnishes an adequate barrier during transsphenoidal hypophysectomy. In the remaining 62%, the diaphragma was extremely thin over some portion of the pituitary gland. It was concave when viewed from above in 54% of the specimens, convex in 4%, and flat in 42%. Even when flat, it lies below the plane of the upper surface of the anterior clinoid process so that a medially projecting supradiaphragmatic lesion, such as an aneurysm, may seem on neuroradiological studies to be located below the anterior clinoid and within the cavernous sinus when they are above the diaphragm in the subarachnoid The opening in the diaphragm's center is large when compared with the size of the pituitary stalk. The diaphragm opening was 5 mm or more in 56% of our cases, and in these, it would not form a barrier during transsphenoidal pituitary surgery. The opening was round in 54% of the cases, and elliptical with the short diameter of the ellipse oriented in an anterior-posterior direction in 46%. A deficiency of the diaphragma sellae is assumed to be a precondition to formation of an empty sella. An out pouching of the arachnoid protruded through the central opening in the diaphragma into the sella turcica in approximately half of the patients. This out pouching, if opened, represents a potential source of postoperative cerebrospinal fluid leakage.

Ferrari AJM[5], stated in their study that the diameter of the hypophyseal foramen was always larger than the pituitary stalk. The depth of the hypophyseal cistern (located in the free space around the pituitary stalk) was less than 2 mm. They found out that in the fetus, the diameter of the hypophyseal foramen was particularly large. The foramen is said to become proportionally smaller during development, and some empty sella turcica are considered to be the consequence of persistence in the adult of a large hypophyseal foramen. It has been hypothesized that normally the diaphragma sellae performs a protective role for the sellar contents, but dehiscence of the diaphragm could allow the pulsating cerebrospinal fluid to enlarge the hypophyseal cistern, leading to an empty sella.

Hardy and maira et al[8] showed in their series of 266 patients subjected to transsphenoidal hypophysectomy for metastatic breast cancer or diabetic retinopathy, Hardy and Maira observed an incompetent or completely absent sellar diaphragm in 76 patients (28.5%). Sellar arachnoidal diverticulum was found in 41patients (15.4%) and was always associated with a large or absent sellar diaphragm.

R. Bryan mason in 1997, [20] reported 10 cases of patients with adrenocorticotropic hormone (ACTH)–secreting pituitary adenomas that originated in the infundibulum or extended into the infundibulum through the opening of the diaphragma sella. All patients underwent transsphenoidal selective adenomectomy and showed laboratory and clinical remission of their hypercortisolism. The arachnoid of the suprasellar cistern was intentionally entered in the other eight patients. To remove cerebrospinal fluid (CSF) for exposure of the tumor and the contiguous infundibulum, positive pressure ventilation was used to deliver CSF into the field, where it was aspirated. After tumor removal, the opening in the arachnoid and diaphragma sella was occluded by an abdominal fat graft in the eight patients who underwent arachnoid exploration. In these cases he opened diaphragma sella in the anteroposterior direction to reach the supra sellar componant of the adenoma and found that it was safer than trans cranial approach which is associated with more postoperative hypopituitarism.

Micheal R.Sagie et al,[28] examined formalin fixed one hundred sphenoid bones obtained from cadavers and their study shows that apart from the passage of the infundibulam the diaphragma sella is complete in only less than 50% of cases. In the majority of specimens with complete diaphragm, dura becomes progressively thinner towards the centre, and in several specimens it was simply a thin membrane through out with the gland clearly visible beneath. Marked variation in the width of tuberculam sellae and dorsum sellae led to gross differences in the macroscopic appearance of diaphragma sellae as viewed from above.

Guilo maira [18]***et al*** , examined 142 patients with empty sella syndrome and confirmed the established role of diaphragma sella morphology in empty sella syndrome.

Ilya Laufer et al,[14] emphasized the extended transsphenoidal approach by using endoscope through the normal sella for supra diaphragmatic lesions. This needs resection of diaphragma sella. The advantages of the extended transsphenoidal approach over a traditional craniotomy are the avoidance of frontal or temporal lobe retraction or sylvian fissure dissection and the potential associated brain injury. In one report, 10% of transcranial skull base procedures resulted in some form of retraction injury to the brain. However, it has been generally thought that safely reaching a suprasellar lesion via the transsphenoidal approach requires the sella to be enlarged and invaded with pathophysiology. This caveat is partially based on the use of the traditional operating microscope, because the light source and lens are a long distance from the lesion, and visualization is limited by long, narrow retractors. The endoscope circumvents this problem by bringing the light source and lens closer to the pathophysiology. A panoramic view is provided and can be augmented by the use of angled endoscopes. Authors of two prior publications have described a purely endoscopic, extended trans sphenoidal approach to suprasellar pathophysiology, but very few cases were actually presented.

Giulio maira et al,[19] emphasized that trans diaphragmatic approach even in normal sella in their study. They stated that transsphenoidal surgery has traditionally been restricted to the removal of tumors involving the pituitary sella and to the suprasellar extension of such tumors if the sella appears enlarged. Craniopharyngiomas located entirely within the suprasellar area together with a normal-sized sella turcica have generally been considered to be not manageable by TSS. In such cases, either pterional (fronto temporal) craniotomy has been used for a more complete removal. Recently, however, two modified transsphenoidal approaches, despite the presence of a normal pituitary fossa, have been proposed for treatment of these craniopharyngiomas. Transsellar–transdiaphragmatic method of approaching the suprasellar cisterns has been reported in the excision of both craniopharyngiomas and pituitary adenomas, with splitting and displacement of the pituitary gland. We have used this approach in two cases of entirely suprasellar retrochiasmatic craniopharyngiomas, in which a total removal was thought to be difficult to achieve using trans cranial surgeries. If the diaphragma sellae was congenitally deficient or absent or enlarged by the tumor or if the transsphenoidal route was used to approach a suprasellar tumor, then an intra operative CSF leakage could occur. In such cases, the sellar cavity was filled with Gelfoam and closed using a fragment of nasal bone placed epidurally and glued to the boundaries of the sella to reconstruct its floor.

Youssef AS [34] ***et al*** stated that the indication most often cited for a transcranial approach is the dumbbell shaped pituitary adenoma with a narrow waist. Prediction that the tanssphenoidal approach will fail in a specific narrow waisted case includes consideration of tumor compression into the sella by intraoperative lumbar intrathecal injection of sterile saline and endoscopic navigation of the opening in the diaphragma sellae.

Kaptain GJ [10] ***et al*** emphasized that Transsphenoidal / Trans diaphragmatic approach requires special knowledge of the anatomy of the circular sinus, diaphragma sellae, tuberculam sellae and planum sphenoidale. Also avoidance of CSF leak by repairing sellar floor is important.

Obrador.S[22] ***et al*** revealed that the dehiscent diaphragma sellae transmit the CSF pulsations in to sella and leads to empty sella syndrome. This theory confirmed by Gibby[13] et al. In contrast, all deficient or absent diaphragma sellae could not be associated with an empty sella syndrome.[3]

Saike. N. et al [29]analysed the sellar morphology and infundibulate neurohypophyseal system (INH) in case of pituitary adenomas .The adenoma shapes were divided into two types according to presence (hourglass type) and absence (barrel type) of indentation. Indentation of the adenoma surface is considered to originate as follows: The bony opening of the sella turcica is 10.5 mm (range, 5–16 mm) in antero posterior diameter and 14 mm (range,10–16 mm) in width (8–10mm). Since the diaphragmatic opening ranges from 3 to 9mm and is narrower than the bony aperture (8–10mm), the margin of the diaphragma sellae may form an indentation on the adenoma surface, extending above the diaphragm. Thus, the degree of development or firmness of the posterior or lateral margin of the diaphragma sellae is reflected as indentation of the adenoma in sagittal and coronal MR sections. Other anatomic and tumor factors, such as internal carotid artery, optic structures, adenoma firmness, and growth direction may determine where and how readily the indentation is formed. The hourglass-type adenoma with indentation was substantially more common in the PPBS-visible group. Careful MR imaging observations of the hourglass type demonstrated the distal end (pituitary gland side) of the PPBS to (pituitary gland side) of the PPBS to be constantly located above the indentation, where the transportation process of ADH granules is considered to be blocked by the diaphragm. In the barrel type, PPBS was demonstrated in varying Locations, such as in the sella, at the distal pituitary stalk above the diaghragm, along the whole pituitary stalk, or in a combination of these areas. In the barrel type, lack of a particular blockage site may result in the accumulation of neurosecretory granules at any portion along the INH system. Thus, the degree of development of indentation may affect the intensity of transportation interruption and the resulting blockage of neurosecretory granules at the pituitary stalk.

Postoperative persisting diabetes insipid us was present in two (4%) of 55 patients in the PPBS-visible group and in four (29%) of 14 patient in the PPBS nonvisible group. Postoperative diabetes insipidus markedly occurs in patients in the PPBS-non visible group and its occurrence may be predictable on preoperative MR images. Its presence shows functional integrity of the INH system in patients with adenoma. However, its absence does not necessarily imply impaired function of the INH system, since lack of or difficulty in PPBS identification is attributable to various factors, such as the presence of coexisting large areas of high signal intensity, tumor size, or even normal variation. Absence of PPBS in the pituitary gland has been reported in 0%– 15.6% of normal subjects without diabetes insipides. Although the clinical importance and usefulness of PPBS evaluation at preoperative T1-weighted MR imaging in pituitary adenomas is yet to be determined, the presence of PPBS should be included as one radiological sign in the evaluation of the functional integrity of the INH system in patients with large pituitary adenomas. When preoperative PPBS is absent, endocrinological evaluation of INH system should be performed. Because post operative persistent diabetes insipidus is more common in PPBS non visible group.

AIMS & OBJECTIVES

1. To analyse the diaphragma sella morphometry in relation with pathological and surgical implications.

2. To establish the anatomical details, normal as well as variations which influence certain pathological conditions involving sella and the surgical avenues to sellar and supra sellar locations.

3. To analyse the morphology of diaphragma sellae, types of shape of sellar opening and position of pituitary stalk including dimensions of sellar opening as well as pituitary stalk.

MATERIALS & METHODS

Fresh cadavers were dissected during post mortem examination at the Forensic lab, Department of Forensic medicine at Government Rajaji Hospital, Madurai.

STUDY PATTERN

This is a prospective study done over a period of six months on fifty fresh cadavers which were randomly selected.

EXCLUSION CRITERIA

1. Cadavers in which anatomy could be distorted due to head injuries.
2. Cadavers in which macroscopic pituitary disease seen.
3. Cadavers in whom, where the postmortem could not be done less than twelve hours.
4. Cadavers in which there were burns involving the head.
5. Cadavers below the age of seventeen years.

REASONS FOR THIS EXCLUSION CRITERIA

In case of head injuries, especially fractures involving skull base distorts the normal anatomy. In case of pituitary diseases particularly pituitary macroadenomas alter the anatomy of diaphargma sella. In old cadavers which is more than twelve hours old, advanced putrefaction process impairs the quality of tissues like fragility as well as elasticity. In cases of burns involving head and neck area, desiccation and dehydration affects the measurements. To avoid the variations due to age related changes, cadavers less than seventy years are excluded.

INCLUSION CRITERIA

Cadavers which are excluded by the above said criteria were Included.

METHODS

DISSECTION TECHNIQUE

The cadaver was placed in supine position. Head of the cadaver was supported on a wooden block. Bicoronal incision was made by starting from root of zygoma in front of tragus towards opposite side same point. Scalp flap was everted in anterior and posterior directions in the sub galeal plane manually as well as by using same osteotome. Cranial vault was inspected to rule out anatomical distortions such as fractures particularly in case of mode of death not known.

Pencil mark was made on the skull by encircling it horizontally, about one cm above supra orbital margin and external occipital protuberance, saw cut made along this line up to inner table. To break the inner table osteotome was used. Sagittal cut was made bilaterally along the superior sagittal sinus to the extent of the exposure, another cut was made circumferentially along the edges.

Falx cerebri detached from crista galli. Both frontal lobes were retracted from the anterior cranial fossa intradurally with tearing of olfactory nerves, optic nerves and optic chiasm were exposed. Both optic nerves were resected 5 to 10 mm distance from its entrance in to optic canal. This exposes the internal carotid arteries with the infundibulum passing vertically to the hypophysis between them. Internal carotid arteries were resected at its supra clinoidal portion. Infundibulum was resected just distal to its entrance in to diaphragma sella.

Posterior part of hemispheres were elevated from the tentorial surface. The brain was allowed to fall backwards so as to draw the brainstem away from the anterior wall of the posterior cranial fossa and bring the cranial nerves in to view. Both cerebral hemispheres are removed with resection of brainstem at the level of midbrain.

For measurement purpose, vernier calliper was used. Micro scissors and jewellers forceps was used for dissections around sellar region.

Antero posterior diameter and transverse diameter of opening of diaphragma sella measured by the use of vernier calliper.

Shape of the opening and position of the stalk in relation with sellar opening documented. Thickness of the diaphragma sella was observed.

MORPHOLOGY OF DIAPHRAGMA SELLA

Diaphragma sella which is a dural membrane had full thickness up to its free margins at the sellar opening in some cases. In some cases it appeared as progressively thinning towards its opening. In few cases there was complete absence or walls of membrane attached at its margins. Based on these findings diaphragma sella was classified in to three types as follows:

(1) Type A was defined as thickness of the membrane is uniform up to its margins of opening.

(2) Type B was defined as gradual thinning of membrane towards the margins of opening.

(3) Type C was defined as deficient or absence of membrane except for thin veils of membrane at its margins.

DIAPHRAGMA SELLA OPENING

The central opening for the pituitary stalk was not uniform in all cases. It appears circular, oval in coronal as well as sagittal plane, and triangular with apex towards ventral, dorsal, right or left.

OPENING OF DIAPHARGMA SELLA

Diaphragma sella contains opening for pituitary stalk. This opening was classified in to various types depending on its shape.

A. Circular.

B. Elliptical.

1. Elliptical in coronal plane.
2. Elliptical in saggital plane.

C. Triangular.

1. Apex towards ventral or dorsal.
2. Apex towards right or left.

POSITION OF STALK IN SELLA OPENING

Opening in the Diaphragma sella divided in to seven regions. Cases are grouped according to region in which the stalk occupies.

1. Central.
2. Anterior midline.
3. Posterior midline.
4. Right anterior quadrant.
5. Right posterior quadrant.

6. Left anterior quadrant.
7. Left posterior quadrent.

STATISTICAL ANALYSIS

In this study, Chi-square and t test were used to analyse the values. Chi-square test used for comparing the male and female groups. Student t test was used for comparing type of membrane, type of sellar opening and diameter of sellar opening and stalk dimensions. p value less than .05 taken as significant.

RESULTS

CADAVER DETAILS

Totally fifty cadavers were examined for this study. Age varies from 20 to 65 years, with the mean age is 47. Among the 50 cadavers, 29 are males, 21are females. Mean age for females is 30 and mean age for males is 22.

SEX DISTRIBUTION

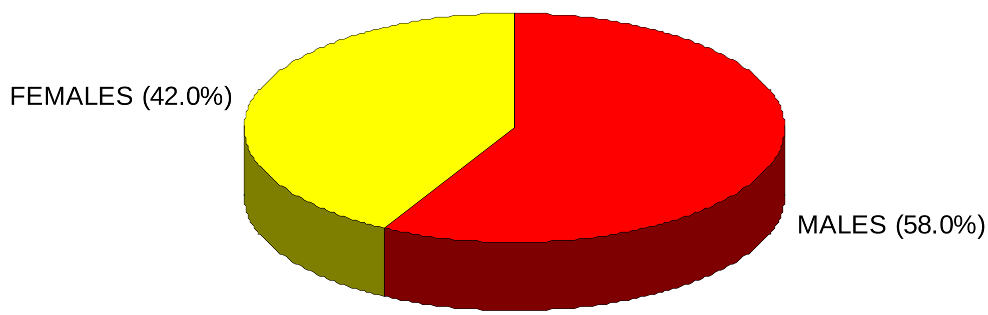

Table - 1 : Sex Distribution

No. of males	29 (58 %)
No. of females	21 (42 %)
Total	50

AGE & SEX DISTRIBUTION

Totally fifty cadavers were studied. Among them 29 were male, 21 were female cadavers. Age distribution among male cadavers as follows, 7 cadavers in the 20 to 30 age group. 9 cadavers in 30 to 40 age group. 9 cadavers in 40 to 50 age group. 3 cadavers in 50 to 60 age group.1 patient in above 60 age group. Age distribution in female cadavers as follows, 7 cadavers in 20 to 30 age group. 5 cadavers in 30 to 40 age group. 5 cadavers in 40 to 50 age group. 2 cadavers in 50 to 60 age group. 2 cadavers in above 60 age group.

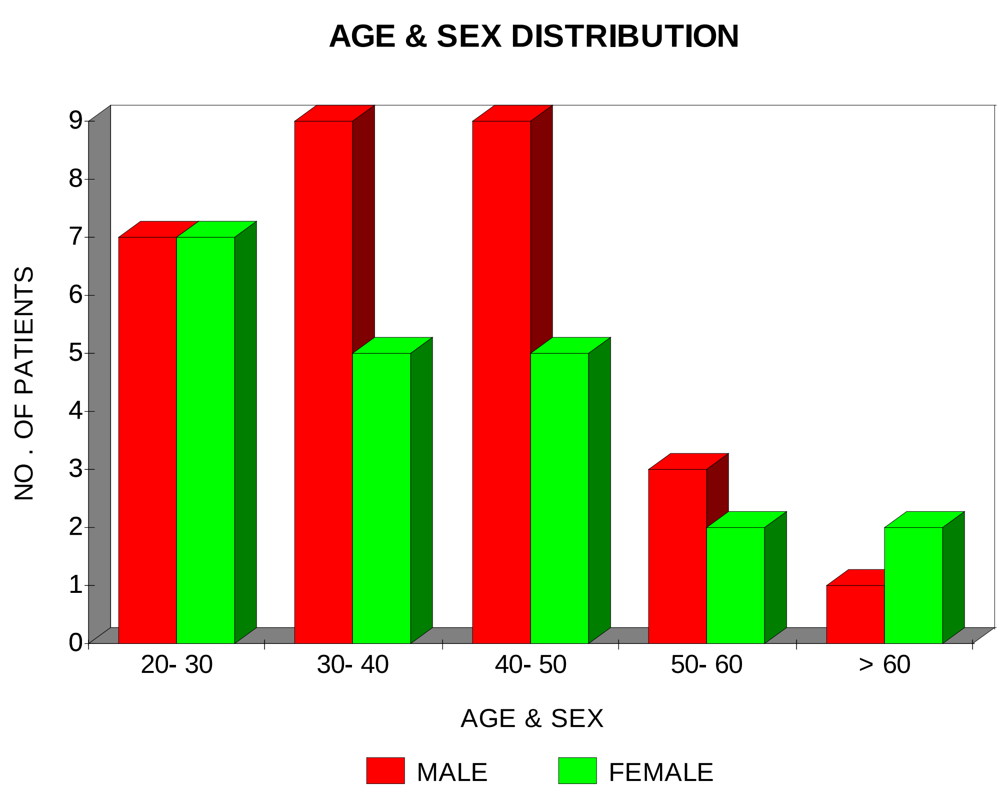

Table – 2 : Age & Sex Distribution

AGE GROUP	MALE	FEMALE	TOTAL
20- 30	7	7	14
30- 40	9	5	14
40- 50	9	5	14
50- 60	3	2	5
> 60	1	2	3

MORPHOLOGY OF DIAPHRAGMA SELLA

Morphology of diaphragma sella is not uniform in all cadavers. It can be easily recognized by observing its margins at its opening. In eleven cadavers, dural membrane was of full thickness at its margins of opening. Among them 7 were male, and 4 were female cadavers.

In thirty-one cadavers sella dura became membranous towards stalk opening. Normal thickness of the dura at the periphery gradually transformed in to a transparent membrane. Among them 18 were male and 13 were female cadavers.

In eight cases diaphragma sella is partially or completely absent and veils of thin membrane covers the hypophysis. Among them 4 were male and 4 were female cadavers.

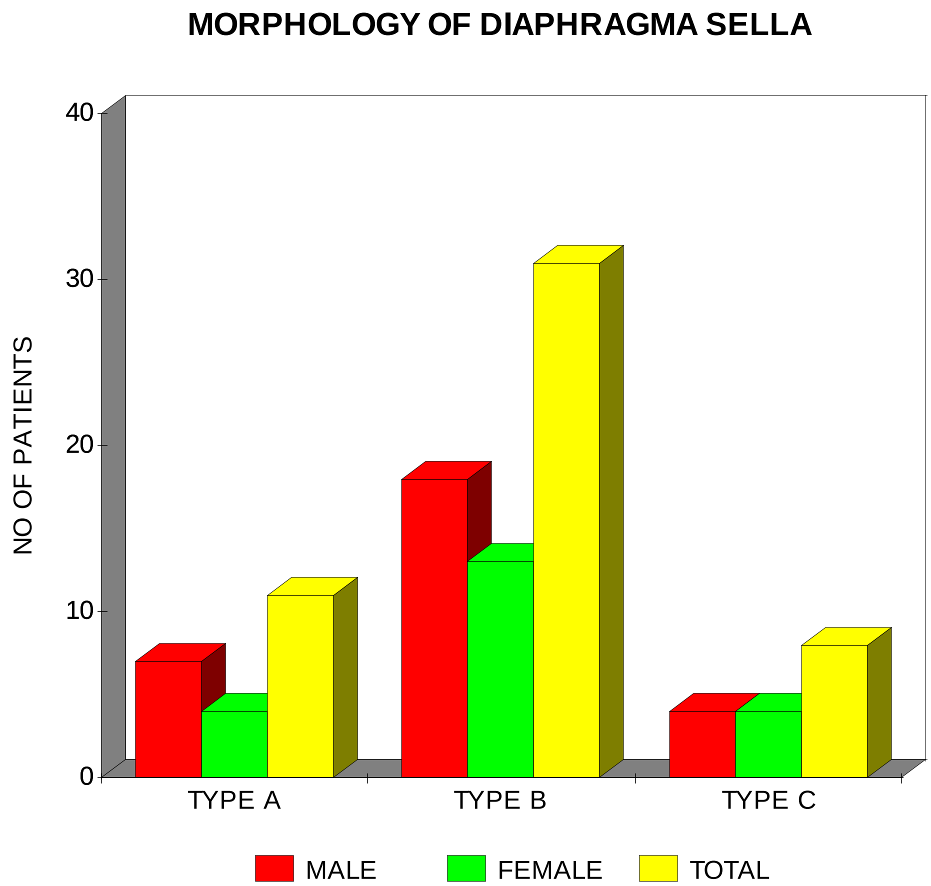

Table – 3 : Type of Diaphragma sella & its distribution

TYPES	MALE	FEMALE	TOTAL
TYPE A	7	4	11
TYPE B	18	13	31
TYPE C	4	4	8

While calculating t & p values for total no., of type A, B, & C, as follows,

Table - 4 : t and p values for the Diaphragma Sella (D S) Morphology

TOTAL NO.	TYPE A&B	TYPE B&C	TYPE C&A
t value	3.1440	3.8177	0.5433
p value	0.0022	0.0002	0.5881

While comparing type A, B, & C among male and female cases, t & p values as follows,

Table - 5 : t and p values for the DS type in male group

MALES	TYPE A&B	TYPE B&C	TYPE C&A
t VALUE	2.2370	3.1320	0.7209
p VALUE	0.0276	0.0023	O.4727

Table – 6 : t and p values for the DS type in female group

FEMALES	TYPE A&B	TYPE B&C	TYPE C&A
t VALUE	2.2361	2.2361	2.2229
p VALUE	0.0276	0.0276	1.0000

Based on the p values type B diaphragma sellae is the most common type also, type B membrane was the most common type in males as well as females.

SHAPE OF THE OPENING

Shape of the opening was observed in all the cadavers. In twenty one cases opening for the stalk was oval in coronal plane. Among them 13 were male and 8 were female cadavers. In five cases it was oval in sagittal plane. Among them 1was male and 4 were females. In seventeen cases it was circular. Among them 12 were male and 5 were female. In eight cases it looked triangular in nature. Among these cases of triangular opening apex of the triangle pointed dorsally in four cases, in one case it pointed ventrally, and in one case apex pointed to the right side. In no cases apex of the triangle pointed left side. Among them 4 were males and 3 were females. Distribution of the total cases according to type of sellar opening as follows,

Table – 7 : Types of Diaphragma Sella opening

TYPE OF SELLAR OPENING	**CIRCULAR (A)**	**ELLIPTICAL (B)**	**TRIANGULAR (C)**
MALES	12	14	4
FEMALES	5	12	3
TOTAL	17	26	7

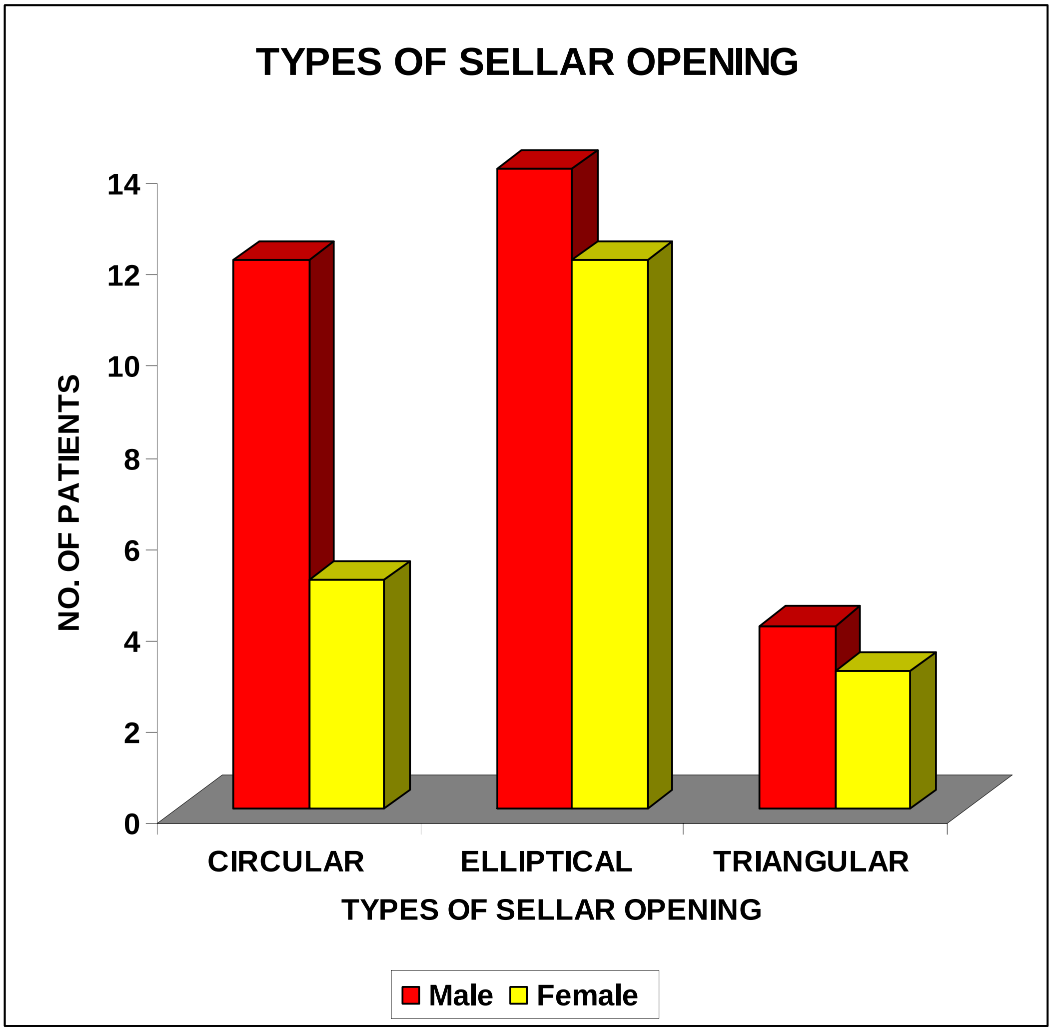

Table – 8 : t & p values for total no., of cases

TYPES	TYPE A&B	TYPE B&C	TYPE C&A
t VALUE	1.3077	3.1739	0.7431
p VALUE	0.1940	0.0020	0.4592

Table – 9 : t & p values for male cases.

MALES FEMALES	TYPE A&B	TYPE B&C	TYPE C&A
t VALUE	1.3077	3.1739	1.7232
p VALUE	0.1940	0.0020	0.0880

Table – 10: t & p values for females cases

FEMALES	TYPE A&B	TYPE B&C	TYPE C&A
t VALUE	1.6589	2.3248	0.5717
p VALUE	0.1050	0.0252	0.5707

Based on these values, Elliptical opening in the diaphragma sellae is the most common type, as well as the most common type in both sex groups.

DIMENSIONS OF THE SELLAR OPENING

Dimensions of diaphragma sella opening are as follows,

Mean anteroposterior diameter in male cadavers was 5.96 mm.

Mean anteroposterior diameter in female cadavers was 5.90 mm.

Mean transverse diameter in male cadavers was 7.74mm.

Mean transverse diameter in female cadavers was 6.96 mm.

Mean anteroposterior diameter in total cadavers was 5.93 mm.

Mean transverse diameter in total cadavers was 7.41 mm.

Table – 11 : Dimensions of the sellar opening

DIAPHRAGMA SELLA OPENING	ANTEROPOSTERIOR DIAMETER	TRANSVERSE DIAMETER
MALE	5.96 mm	7.74mm
FEMALE	5.90 mm	6.96 mm
TOTAL CASES	5.93 mm	7.41 mm

Anteroposterior and transverse diameter of sellar opening was analyzed on the whole, as well as male and female groups separately.

Table - 12 : t and p values of sellar opening

SELLAR OPENING	TOTAL CASES	MALES	FEMALES
t VALUE	2.14	1.79	1.08
p VALUE	0.0348	0.0782	0.2853

Based on this analysis , transverse diameter was more than antero posterior diameter in total number of cases, but taking male and female groups separately there was no significant difference between antero posterior and transverse diameter of diaphragma sellae opening.

Among the 50 cases, largest antero posterior diameter was 9.8 mm. and smallest antero posterior diameter was 2.8 mm. Largest transverse diameter was 15.5 mm and smallest transverse diameter was 2.8 mm.

DIMENSIONS OF PITUTARY STALK

Antero posterior and transverse diameters of pituitary stalk as follows,

Mean antero posterior diameter in male cadavers was 1.91mm.

Mean antero posterior diameter in female cadavers was 2.05mm.

Mean transverse diameter in male cadavers was 2.37mm.

Mean transverse diameter in female cadavers was 2.40 mm.

Mean antero posterior diameter in total cadavers was 1.97 mm.

Mean transverse diameter in total cadavers was 2.38 mm.

Table - 13: Dimensions of the pituitary stalk

PITUITARY STALK (DIAMETER)	ANTERO POSTERIOR	TRANSVERSE
MALES	1.91mm	2.37 mm
FEMALES	2.05mm	2.40 mm
TOTAL CASES	1.97mm	2.38 mm

Statistical analysis of pituitary stalk dimensions, comparing Antero posterior and transverse diameters as follows,

Table – 14 : t and p values of the dimensions pituitary stalk

	TOTAL	MALE	FEMALE
t VALUE	2.17	1.86	1.19
p VALUE	0.0321	0.0685	0.2396

Transverse diameter is more than antero posterior dimension in total number of cases. But there is no significant difference between Antero posterior and transverse diameter in male and female cadavers taken separately.

Among the 50 cases largest antero posterior diameter and transverse diameters were 3.8 and 4.3 respectively. Smallest antero posterior and transverse diameters were same as 0.8 mm.

POSITION OF THE PITUITARY STALK

Position of stalk in relation to opening of diaphragma sella was documented in all cases. Sellar opening was divided into eight areas, including four quadrants, anterior midline, posterior midline and central region.

In twenty-two cadavers, the stalk occupies central region of the sellar opening. In twenty one cadavers stalk occupies posterior midline region. In four cases it occupies anterior midline region. In one case stalk passes through left anterior quadrant. In two cases stalk passes through left posterior quadrant.

The right anterior as well as posterior quadrants of sellar opening did not contain stalk in any of the cases.

Table – 15 : Distribution of stalk position

POSITION OF STALK	NO. OF PATIENTS
Central	22
Midline posterior	21
Midline anterior	4
Left anterior quadrant	1
Left posterior quadrant	2

DISCUSSION

Diaphragma sella is a dural membrane, which extends from the oculo motor triangle bilaterally. The roof of the cavernous sinuses and diaphragma sellae are a part of a single horizontal dural layer that joins the two anterior petroclinoid folds[4]. Laterally, the direction of this layer changes; it becomes the lateral wall of the cavernous sinus and joins the dura mater of the middle cerebral fossa. On the midline, this layer balloons toward the sella through the diaphragmatic foramina, creates a dural bag containing the hypophysis, and attaches to the inferior aspect of the diaphragma sellae [4]. As a consequence, no straight sagittal dural wall exists between the pituitary gland and cavernous sinus; the lateral border of the hypophyseal fossa is a part of this antero posterior and supero inferior convex bag. In classical text it was considered that medial wall of cavernous sinus formed by a single layer of dura that attached at a sagittal line where the diaphragma sella continues as roof of cavernous sinus.

From the observations, diaphragma sella could be classified in to three types as follows,

1. Type A is defined as thickness of the membrane is uniform up to its margins of opening.

2. Type B is defined as gradual thinning of membrane towards the margins of opening.
3. Type C is defined as deficient or absent of dura and veils of thinning membrane covers the roof of hypophysis.

This classification is mainly based on thickness of the membrane at its margins of sellar opening compares to periphery.

In our study, 22% of type A cases, 62% cases of type B and 16% cases of type C were found. Type B is the most common type in total as well as males and females. Moreover, most of type A diaphragma sella had a circular opening and most of type B and type C cases were associated with an oval opening.

Regarding shape of the opening, elliptical opening was the most common type in both male group and female group and thereby is the dominant shape seen in this series. Transverse diameter of the sellar opening is more than the antero posterior diameter. Likewise transverse diameter of the pituitary stalk is more than the anteroposterior diameter.

In an earlier anatomic study, Renn and Rhoton [24] found that the diaphragma was at least as thick as one layer of dura in 38% and in most cases it furnishes an adequate barrier during transsphenoidal hypophysectomy. In the remaining 62%, the diaphragma was extremely thin over some portion of the pituitary gland. In our study this includes type B and type C which was 78%. Hardy and Maira[8]observed incompetent or completely absent sella in 28% of their cases in contrast to 16% in our series. Incompetence of the sellar diaphragm in humans has been demonstrated in 22 to 77% of cases in the series by Busch [3], kaufman [11] and Bergland [2].

Busch, in his study of 788 sellae without history of pituitary disorders[3], classified diaphragma sellae in to following categories, which were later resorted by Kaufman in 1972.

Type 1-a	:	The diaphragma sella forms a complete seal.
1-b	:	Slight tunnel shaped depression in the intact diaphragma sella
Type 2-a	:	An opening, 3mm or smaller, in the diaphragma sellae exists around the hypophyseal stalk
Type 2-b	:	A slight funnel shaped indentation towards middle of sellae.

Type 3-a : The diaphragma sella is composed of 2 mm or smaller peripheral veil leaving the gland freely exposed and covered with arachnoid.

Type 3-b : Diaphragma sella as in 3a but pituitary gland Intended often displaced eccentrically.

Type 3-c : Diaphragma sella as in 3a but pituitary gland is markedly intended.

Based on the classification proposed by Busch, in our study, there was only one case similar to type 2 and 8 cases similar to type 3.

There were two cases which appeared as a complete seal but it was the upper pole of the pituitary gland which occupied the opening, but not stalks. Hence, no cases typical of type 1 diaphragma sella were seen.

Our proposed system of classification is simpler and easily reproducible. In the endoscopic era, where the transsellar trans diaphragmatic approach for suprasellar lesions are gaining widespread acceptance, the knowledge about morphology of diaphragma sellae is essential.

Diaphragma sella morphology is also developmentally important, because of its influence on morphology of hypophysis. Usually it hampers the CSF pulsations in to sella. In cases where the sella is deficient or absent, hypophysis appears small as well as displaced posterior and inferiorly[5.]

Morphology of pituitary adenomas depends on the morphology of diaphragma sella[24]. Usually it extends superiorly in the figure of eight configuration (hour glass appearance) or barrel shaped appearance.

Full thickness diaphragma sella with narrow opening is responsible for figure of eight appearance. Incomplete [or deficient] or membranous diaphragma sella, that is, type B or type C membranes associated with barrel shaped pituitary adenomas. Also cranial extension is more common than parasellar extension which is due to invasive nature of lesion. This is because of the least resistance offered by diaphragma sellae and supra sellar cisterns [25].

In cases of pituitary adenomas, visualization of posterior pituitary bright substance (PPBS) denotes the integrity of infundibulo neurohypophysis system.[29] Visualization of PPBS more common in adenomas which has hour glass configuration than barrel shaped pituitary adenomas. PPBS is visible more often above the diaphragma sella in hour glass shaped adenomas. PPBS is less frequently visible with the barrel shaped adenoma. The shape of the adenoma, that is, the hourglass or the barrel type, is determined by the degree of diaphragmatic development and influences the relocation site of PPBS. Postoperative permanent diabetes insipidus is more common in cases where PPBS is not visualized.

In cases where the diaphragma sella was absent, pituitary gland enlarges and becomes convex upwards. Simmon et al[30] observed that**,** infundibulum retains its relationship to the posterior rim of defect and adjacent to dorsum sella in cases where diaphragma sella were deficient. Contrary to his observations, in our 8 cases of deficient diaphragma sellae only 3 cases showed the above findings. In 5 cases it remained at the centre of the sellar opening.

Clinical presentation of chiasmal compression may depend on the morphology of diaphragma sella. If the diaphragma sella is intact and stretches over the tumor, classical bitemporal hemianopia develops. In cases of deficient diaphragma sella, chiasmal compression becomes irregular and gives rise to atypical field defects.

Primary Empty Sella Syndrome represents a complex and evolving syndrome in which intracranial pressure and CSF dynamics alterations together with an incompetent sellar diaphragm play a clear patho genetic role [18]. Incompetence of the sellar diaphragm in humans has been demonstrated in 22 to 77% of cases. Most of these defects do not result in herniation of the subarachnoid space, however. These data confirm that the anomaly of the sellar diaphragm is essential for the development of the empty sella, although other factors seem to be relevant as well. The role of intracranial hypertension and alteration of CSF dynamics also involves in the formation of empty sella syndrome[18].

Morphology of the sella also influences surgical excision of adenomas which are arising from pituitary stalk[20.] In cases where the diaphragma sella is complete, it needs resection in anteroposterior direction in order to excise the adenomas.

Transsphenoidal surgery has traditionally been restricted to the removal of tumors involving the sella and to the suprasellar extension of such tumors if the sella appears enlarged.

Craniopharyngiomas located entirely within the suprasellar area together with a normal-sized sella turcica have generally been considered to be not manageable by transspenoidal surgery. In such cases, either pterional or frontotemporal craniotomy has been used for a more complete removal. Recently, however, two modified transsphenoidal approaches[19], despite the presence of a normal pituitary fossa, have been proposed for treatment of these craniopharyngiomas.

The transsellar–trans diaphragmatic method of approaching the suprasellar cisterns has been reported in the excision of both craniopharyngiomas and pituitary adenomas, with or without splitting and displacement of the pituitary gland. This approach extremely useful in retro chiasmatic lesions in which a total removal was thought to be difficult to achieve using trans cranial surgeries. This trans diaphragmatic approach needs resection of diaphragma sella in the anteroposterior direction.

Type A diaphragma sella usually protects the supra sellar structures during trans sphenoidal surgery, but the diaphragma is frequently thin, tenuous structure, which would not be an adequate barrier for the protection of the suprasellar strutures during trans sphenoidal surgery [25]. In case of thinned diaphragma sella or deficient sella with intrasellar arachnoidocele ,it is more prone for intra operative CSF leak due to inadvertent entry into sub arachnoid space.

These cases need repair of sellar floor to prevent post operative CSF. In such cases, the sellar cavity was filled with gelfoam and closed using a fragment of nasal bone placed epidurally and glued to the boundaries of the sella[17].

Even though the cranial extension is more common, there is a sub group of tumors, the invasive adenomas that preferentially grow through the rigid bony floor or into cavernous sinus rather than taking the path of least resistance into suprasellar cistern [27].

Transphenoidal surgery usually indicated in subdiaphragmatic lesions associated with enlarged sella, but recently after the introduction of endoscopes, improved microscopes and micro instruments, handling of supra diaphragmatic lesions by using modified transsphenoidal approach is also possible to remove supradiaphragmatic tumors while preserving remaining normal pituitary tissue, even in the context of a normal-sized sella.

Trans cranial approaches to the suprasellar region involve certain risks. For instance, the midline sub frontal approach necessitates retraction of the frontal lobes. The pterional approach requires separation of the sylvian fissure and retraction of the frontal and temporal lobes. Likewise, the sub temporal approach requires significant retraction of the temporal lobe. Brain retraction continues to be a major source of iatrogenic brain injury, potentially resulting in infarction, hematoma, or regional brain atrophy.

Transsphenoidal procedures also carry their own inherent risks.

These include persistent postoperative CSF rhinorrhea and postoperative meningitis. Because the subarachnoid space is deliberately entered during this modified procedure, the surgeon must manage the large opening in the arachnoid made at surgery. However, the consequences of these complications are, in general, less significant and less permanent than those of transcranial surgery. This is supported by the minimal risks of perioperative morbidity and mortality associated with transsphenoidal surgery. In addition, transsphenoidal procedures are generally more direct and less time consuming than transcranial operations. These observations have led to the generally accepted notion that, when safe removal is possible through a transsphenoidal approach, it is preferred over a transcranial one. However, transsphenoidal surgery is generally avoided in patients with a normal-sized sella, in growing children, and in patients with normal preoperative pituitary function [15-17]. This avoidance stems from the fears of damage to the hypothalamopituitary axis that can occur with an entirely transsellar exposure of the suprasellar space. Unfortunately, transcranial surgery also produces deficiency. Using the modified transsphenoidal approach in the present cases demonstrated that it is possible to remove supradiaphragmatic tumors while preserving remaining normal pituitary tissue, even in the context of a normal-sized or direct biopsy by using a transsphenoidal route[19]. These include Rathke's cleft cysts, optic chiasm or posterior optic nerve gliomas, Hypothalamochiasmatic tumors of childhood, germinomas, granular cell tumors, meningiomas, pituitary adenomas, hemangioblastomas, metastatic lesions, and even certain aneurysms in critical positions.

CONCLUSIONS

Diaphragma sella, a dural layer which forms the roof of the hypophysis has developmental, pathological, as well as surgical implications.

1. According to its morphology it can be divided in to three types.

    1. Type A was defined as thickness of the membrane is uniform up to its margins of opening.
    2. Type B was defined as gradual thinning of membrane towards the margins of opening.
    3. Type C was defined as deficient or absence of membrane except for thin veils of membrane at its margins.

    Among these three types, Type B is the most common type in both sexes.

2. Elliptical opening for stalk is the most common type than circular and triangular openings.

3. Transverse diameter of the diaphragmatic opening is more than anteroposterior diameter.

4. Transverse diameter of pituitary stalk is more than anteroposterior diameter.

5. Pituitary stalk passes through the centre of the diaphragmatic opening in majority of cases.

BIBLIOGRAPHY

1. Annegers JF, Coulam CB Abboud CF, et al :Pituitary adenoma in Olmstead county, Minnesota, 1935-1977. Mayo clinic proc 53 :641- 643,1978.
2. Bergland RM, Ray BS, Torack RM: Anatomical variations in the pituitary gland and adjacent structures in 225 human autopsy cases. J Neurosurg 28:93–99, 1968
3. Busch W: Die Morphologie der Sella turcica und ihre Beziehung enzur Hypophyse. Virchows Arch Path Anat 320:437–458, 1951.
4. Destrieux C, Kakou MK, Velut S, Lefrancq T, Jan M : Micro anatomy of the hyperphysical boundries. J Neurosurg 88 : 743-752, 1998.
5. Ferreri AJM, Garrido SA, Markarian MG, et al: Relationship between the development of diaphragma sellae and the morphology of the sella turcica and its content. Surg Radiol Anat 14:233–239, 1992.
6. Gibby WA, Cohen MS, Goldberg HI, et al: Pseudotumor cerebri: CT findings and correlation with vision loss. AJR 160: 143–146, 1993.

7. Goel A , Nadkarni T , Muzumdar D, Desai K, Phalke U, Sharma P. Giant pituitary tumors : A study based on surgical treatment of 118 cases. Surgical Neurology 61 : 436- 446,2004.

8. Hardy J, Maira G: Microsurgical anatomy in trans-sphenoidal hypophysectomy.J Neurosurg Sci 21:151-157, 1977

9. Honegger J, Buchfelder M, Fahlbusch R, et al : Transsphenoidal microsurgery for craniophrayngioma. Surg Neurol 37: 189-196,1992.

10. Kaptain GJ, Vincent DA, Sheehan JP, Laws ER Jr: Transsphenoidal approaches for the extracapsular resection of midline suprasellar and anterior cranial base lesions. Neurosurgery 49 :94-101,2001.

11. Kaufman B: The “empty” sella turcica- manifestation of the intrasellar subarachnoid space. Radiology 90:931–941, 1968

12. Kouri JK, Chen MY, Watson JC, Oldfield EH : Resection of suprasellar tumors by using a modified transsphenoidal approach Report of four cases. J Neurosurg 92 : 1028- 1035, 2000.

13. Kovacs K, Horvath E : Tumors of the pituitary gland. Atlas of tumor pathology, fascicle 21,2nd series. Washington, D.C., Armed Forces Institute of pathology, 1986,pp 1-269.

14. Laufer I, Anand VK, Schwartz TH: Endoscopic, endonasal

extended transsphenoidal,transplanum transtuberculum approach for resection of suprasellar lesions J Neurosurg 106:400–406, 2007.

15. Laws ER Jr: Transsphenoidal surgery, in Apuzzo MLJ (ed): Brain Surgery. Complication Avoidance and Management. New York: Churchill Livingstone, 1993, pp 357–361
16. Laws ER Jr: Transsphenoidal microsurgery in the management of craniopharyngioma. J Neurosurg 52:661–666, 1980
17. Laws ER Jr: Craniopharyngioma: transsphenoidal surgery. Curr Ther Endocrinol Metab 6:35–38, 1997
18. Maira G, Anile C, Mangiola A :Primary empty sella syndrome in a series of 142 patients. J Neurosurg 103:831–836, 2005
19. Maira G, Anile C, Albanese A, Cabezas D, Pardi F, Vignati A : The role of transsphenoidal surgery in the treatment of craniopharyngiomas. J Neurosurg 100:445–451, 2004
20. Mason BR, Nieman KL, Doppman JL, Oldfield EH : Selective excision of adenomas originating in or extending into the pituitary stalk with preservation of pituitary function. J Neurosurg 87: 343-351, 1997.

21. Montanera W, Kucharczyk W : Imaging of sellar and parasellar lesions. Neuro surgery volume 1, 1253-1272. Robert H. Wilkins & Setti S. Rengachary.
22. Obrador S: The empty sella and some related syndromes. J Neurosurg 36:162–168, 1972
23. Page RB: Craniopharyngioma: indications for transsphenoidal surgery. Curr Ther Endocrinol Matab 5:33–34, 1994
24. Renn WH, Rhoton AL Jr: Microsurgical anatomy of the sellar region. J Neurosurg 43:288–298, 1975.
25. Rhoton AL, Jr.,: The Sellar region. Neurosurgery 51, supplement 1, Oct 2002 s1 335- 374.
26. Rhoton AL Jr : Microsurgical Anatomy of the Sellar Region Neuro surgery volume 1 ,1243-1252. Robert H. Wilkins & Setti S.Rengachary.
27. Sagie MR, Mulligam BP.Sella and its relations . Radiology 1982 volume 145
28. Sagie M R, Blumbergs P C : The Diaphragma sellae : Its Relationship to the configuration of the pituitary gland. Radiology 145 : 703-708, December 1982.
29. Saeki N, Hayasaka M, Murai H, Kubota M, Tatsuno I, Takanashi J, Uno T, Iuchi T, Yamaura A : Posterior Pituitary Bright Spot in

Large Adenomas:MR Assessment of Its Disappearance or Relocation along the Stalk, Radiology 2003; 226:359–365

30. Simmons GE , Suchlike JE , Rak KM , Damiano TR : MR imaging of pituitary stalk : size , shape, and enhancement pattern, AJR 159; 375-377,1992.

31. Taylor SL, Barakos JA, Harsh GR IV , Wilson CB : Magnatic resource imaging of tuberculum sellae meningiomas : preventing preoperative miadiagnosis as pituitary adenoma, Neurosurg 31:621- 627,1992.

32. Thapar K, Laws ER : Pituitary tumors: Functioning and nonfunctioning.Youmans Neurological surgery, 5^{th} edition. pp 1169- 1200.

33. Youssef AS, Agazzi S, Van loveren RH : Transcranial surgery for pituitary adenomas. Operative Neurosurgery : 168-175, vol 57, 2005.

PROFORMA

CADAVER DETAILS

SEX :

AGE:

TYPE OF DIAPHRAGMA SELLA: (mark ✓ at box)

Type A □ Type B □ Type C □

TYPE OF DIAPHRAGMA OPENING : (mark ✓ at box)

Circular □ Elliptical □ Triangular □

POSITION OF STALK : (mark ✓ at box)

1. Central □
2. Anterior midline □
3. posterior midline □
4. Right anterior quadrent □
5. Right posterior quadrent □
6. Left anterior quadrent □
7. Left posterior quadrent □

DIMENSIONS OF SELLAR OPENING

Anteroposterior diameter : -------- mm

Transverse diameter : --------- mm

DIMENSIONS OF PITUITARY STALK

Anteroposterior diameter : -------- mm

Transverse diameter : --------- mm